Effect of liquid and paste-type lubricants on torque values during simulated rotary root canal instrumentation

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Abstract

Peters OA, Boessler C, Zehnder M. Effect of liquid and paste-type lubricants on torque values during simulated rotary root canal instrumentation. *International Endodontic Journal*, **38**, 223–229, 2005.

Aim To evaluate the effects of lubrication on torque generated during rotary preparation of simulated root canals in dentine using ProFile and ProTaper Nickel-Titanium instruments.

Methodology Thirty-two 3 mm thick dentine discs were used for this study. Four pilot holes were drilled perpendicularly through each disc. These simulated root canals were filled with water, aqueous 15% ethylenediamine tetraacetic acid (EDTA) or a paste-type lubricant (Glyde). Empty canals served as controls. Peak torque values and apically directed forces of rotary instruments were measured using a specially designed testing platform. Full torsional loads over time were calculated by integration of continuous torque records. Data were compared using analyses of variance with the alpha-type error set at 0.05.

Results Maximum torque values using ProFile instruments were significantly ($P < 0.005$) reduced by the EDTA solution, whilst no reduction was observed using Glyde. With ProTaper instruments, no lubricant effects on maximum torque values were observed ($P = 0.372$). Full torsional loads over time were significantly reduced for both ProFile and ProTaper preparation ($P < 0.005$) by the use of lubrication. The two fluids performed significantly better than paste-based Glyde. All lubricants reduced force when applied to ProTaper by mean reductions ranging from 12 to 54%, whilst Glyde lead to increased force when applied to ProFile.

Conclusions Under the conditions of this laboratory study, lubrication appeared to be advantageous. Aqueous solutions generally performed better than the paste-type product under investigation, which showed untoward effects when used in conjunction with a rotary instrument with a U-shaped cross-section (ProFile).

Keywords: EDTA, instrument fracture, lubricant, torque value.

Received 18 October 2004; accepted 9 December 2004

Introduction

In root canal treatment, lubricants are mostly used to emulsify and suspend debris that is produced by mechanical instrumentation. Whilst aqueous irrigation solutions such as sodium hypochlorite (NaOCl) and ethylenediamine tetraacetic acid (EDTA) may serve as lubricants, paste-type substances (e.g. Glyde, Dentsply Maillefer, Ballaigues, Switzerland, and RCPrep, Premier Dental, Norristown PA, USA) are specifically marketed for that purpose.

Another purported function of lubricants is to facilitate mechanical action of endodontic hand or rotary files (Ruddle 2002). In a study evaluating the effects of lubrication on cutting efficiency of Hedström and K-files, tap water and 2.5% sodium hypochlorite

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solutions increased the cutting efficiency compared with dry conditions (Yguel-Henry *et al.* 1990).

Nygaard Østby introduced EDTA to root canal treatment procedures in the middle of the last century (Nygaard Østby 1957), whilst NaOCl has been in use for at least 70 years (Walker 1936). Chelating agents such as EDTA create stable calcium complexes with dentine mud, smear layers or calcific deposits along the canal walls. These agents act on calcified tissue by substituting sodium ions, which combine with dentine to give soluble salts for the calcium ions that are then bound in a less soluble combination (Seidberg & Schilder 1974). This may help to avoid apical blockage and aid in disinfection by facilitating access of solutions via removal of smear layer.

Current literature reports predominantly on the mode of action of liquid chelator solutions for root canal irrigation, but little information is available on chelators with paste or gel consistency recommended for use during rotary root canal preparation. However, such paste-type EDTA preparations are recommended by rotary instrument manufacturers to be routinely used together with their products, tentatively to reduce stresses on instruments and/or improve hard tissue debridement.

Sattapan *et al.* (2000) identified two main reasons for instrument fracture: cyclic fatigue and torsional overload. Experiments using a specially designed torque-testing apparatus later detailed torque and force values present in clinical situations (Peters & Barbakow 2002) and the conditions that may lead to instrument fracture, depending on preloading (Ullmann & Peters 2005) and instrument movements. Another approach to reduce fracture incidence are modifications in file cross-sectional design towards more actively cutting files. Recent experiments confirmed reduced torque scores for these new file designs compared with U-shaped cross-sections (Peters & Barbakow 2002, Peters *et al.* 2003).

Moreover, it is believed that the use of paste-like substances as lubricants during rotary root canal preparation can help to reduce the risk of instrument fracture by way of reducing torque values. However, this claim has not been substantiated yet and therefore, the aim of this study was to compare torques generated during rotary preparation in dry or lubricated simulated root canals in human dentine discs. Furthermore, the effects of cross-sectional instrument geometry on torque under lubrication were assessed.

Materials and methods

Preparation of dentine discs

Human third molars free of gross decay and restorations were selected from the department's collection of extracted teeth. Teeth had been stored in 0.1% thymol solution at 5 °C. Crowns were sectioned in the occlusal plane using a diamond-coated saw (SP 1600; Leica, Nussloch, Germany) 2 mm below the central fissure. Subsequently, the crown was sectioned a second time apically from the first cut, resulting in a dentine disc of 3 mm thickness. Discs were inspected under a binocular for possible enamel remnants; discs showing such remnants were discarded. Four pilot holes (0.5 mm diameter) were drilled perpendicularly through the dentine discs with a stationary drill under water-cooling. These holes served as standardized simulated root canals for torque testing. The prepared dentine discs were then stored in distilled water at 5 °C until further use. The discs were then assigned to two main experimental groups ($n = 16$ discs per group) for preparation with size 30 ProFile .06 instruments and ProTaper finishing file 2 (both by Dentsply Maillefer) (Table 1).

Torque-testing platform

A specially designed computer-controlled testing platform described in detail elsewhere (Peters & Barbakow 2002) was used to record values for torque and force during preparation of the simulated root canals in the dentine discs (Fig. 1). In brief, specimens were mounted on a specially designed holder attached to a strain gauge, which was connected to a preamplifier (A & D 30; Orientec, Tokyo, Japan). A torque sensor (MTTRA 2, with amplifier Microtest, both Microtec Systems, Villingen, Germany) and a motor (Type ZSS; Phytron, Gröbenzell, Germany) were mounted on a stable metal platform, which moved along a low-friction guide rail. A linear potentiometer (Lp-100; Midori, Osaka, Japan) was attached to the sliding platform to record linear

Table 1 Experimental groups and variables

Experiment	Instrument	No. of canals	Lubricants	Control
1	ProFile .06 30	64 (16/group)	EDTA, distilled	No medium
2	ProTaper F2	64 (16/group)	water, Glyde	applied

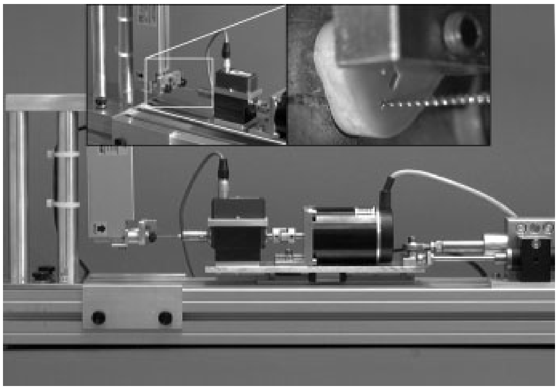

Figure 1 The torque-testing platform described in detail by Peters & Barbakow (2002) was used to record values for torque and force during preparation of the simulated root canals in dentine discs. The dentine discs containing four simulated canals were mounted using a specially manufactured vice, which allowed penetration of the rotary instruments (insert top right).

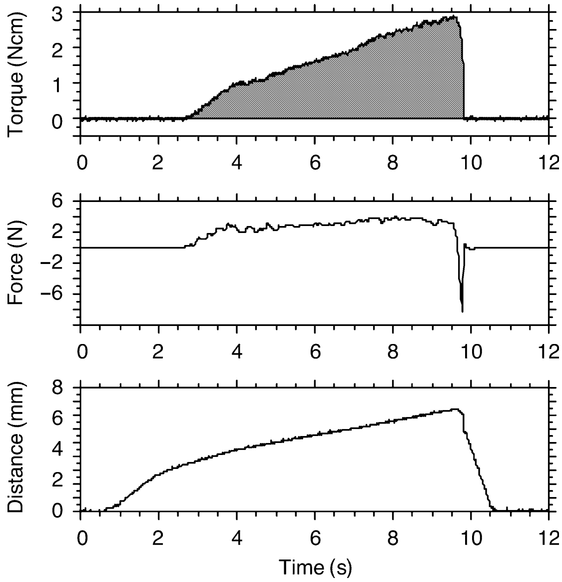

Figure 2 Continuous registration of torque, force and insertion depth during preparation of a simulated root canal in a dentine disc using a ProFile .06 30 instrument. Shaded area represents integrated area to calculate torsional load.

movements. The movements of the instruments relative to the discs were executed by a linear drive (P01-2380; LinMot, Zürich, Switzerland), which was controlled by a computer program called ENDOTEST running on a Macintosh PowerPC computer (Apple Inc., Cupertino, CA, USA).

Data for torque, force and insertion depth were acquired from the sensors via three analogue channels at a sampling rate of 100 Hz using a 12-bit interface (PCI-MIO-16CE; National Instruments, Austin, TX, USA) using the ENDOTEST software package, which was specifically written for that purpose. Variables recorded during each measurement were registered as 'Ncm', 'N' and 'mm', respectively, for torque, force and distance of instrument insertion and were stored in a proprietary format for subsequent off-line analyses (Fig. 2).

Using data from pilot experiments with manual feed, optimized individual feed parameters were programmed for the two experimental groups coding for the instrument insertion speed and depth (Fig. 2, bottom panel).

Lubricants

The following substances were used as lubricants: EDTA 15% w/v in aqueous solution, pH 8, distilled water, Glyde (which contains 15 wt% of EDTA) and no lubricant (control, Table 1). To determine equal amounts of lubricants, the volume for the simulated root canals was calculated under the assumption that the canals were cylinders of 0.59 mm^3. On this basis, it was decided to use 0.5 μL of ETDA solution and water, respectively, and to fill the artificial canal completely with paste-type Glyde. EDTA and distilled water were placed into the simulated canal using a pipette with disposable tip, whilst Glyde was applied with a 26-gauge irrigating needle (Sterican; B. Braun Medical AG, Emmenbrücke, Switzerland) mounted on the original multiple-dose syringe.

Each disc was subjected to all four regimens. To control for differences in dentine structure and positioning of the discs, and to exclude any bias caused by possible carry-over of medicaments, a rolling sequence for the tested media was determined at the beginning of the experiment: canal 1 received no medium, canal 2 was filled with water, canal 3 was filled with EDTA and Glyde was applied to canal 4. This sequence was changed with each subsequent disc, so that each test and control substance was four times in the first, four times in the second, four times in the third, and four times in the fourth canal. To minimize carry-over of lubricants from one artificial canal to the others, discs were mounted so that the canal under investigation faced downward (Fig. 1, insert top right). The appropriate medium was loaded into the simulated canal, the tip of the instrument was positioned at the centre of the pilot hole and ENDOTEST was activated. Between

the four individual tests per disc, these were washed in deionized water. Instruments were cleaned for 1 min using an ultrasonic bath with 100 mL deionized water. Subsequently, the dentine discs were dried using GEPE 'Air Duster' (Image Trade, Safenwil, Switzerland) and again mounted into the holder.

Used Nickel-Titanium (NiTi) rotary instruments were replaced with new ones after preparation of 16 simulated canals. Preliminary tests showed that using a file for 16 simulated canals did not affect the parameters under investigation.

Data analysis

Maximum values for torque and force were calculated off-line (Fig. 2); the full torsional load over time (in 'Ncm s') was calculated by integrating the area under the torque curve (shaded area in Fig. 2). One-way analyses of variance with Scheffé's *post-hoc* tests were employed to compare means amongst various lubricants. Due to variation in control torque scores for the two rotary instruments used, torque data was recalculated and also expressed as changes compared with values obtained without lubrication within the same dentine disc. Comparisons were then made by two-way ANOVA with instrument type and lubrication as the two independent variables. For all tests, the alpha-type error was set at <0.05.

Results

Figure 2(a) illustrates a typical record of the preparation in a simulated root canal 0.5 mm in diameter using a ProFile instrument .06 30 at an average inward feed of 0.5 mm s^{-1}. With no lubrication and air-dried dentine, a mean maximal torque score (±SD) of 2.90 ± 2.01 N cm was recorded (Fig. 3a). Torque scores were significantly ($P < 0.005$) lower when simulated root canals were filled with aqueous EDTA, whilst the application of Glyde did not decrease maximum torque scores (3.01 ± 2.01 N cm, Fig. 3a).

With an inward feed of 0.875 mm s^{-1} (Fig. 2b), the maximum torque score (mean ± SD) for ProTaper F2 was 3.90 ± 2.65 Ncm. However, torque scores were not significantly reduced by any of the applied media ($P = 0.372$, ANOVA, Fig. 3a). Full torsional loads over time were significantly reduced for both ProFile and ProTaper preparation ($P < 0.002$ and 0.001, respectively) by the use of lubrication. The two fluids performed significantly better than paste-based Glyde (Fig. 3b). Apically directed force varied substantially

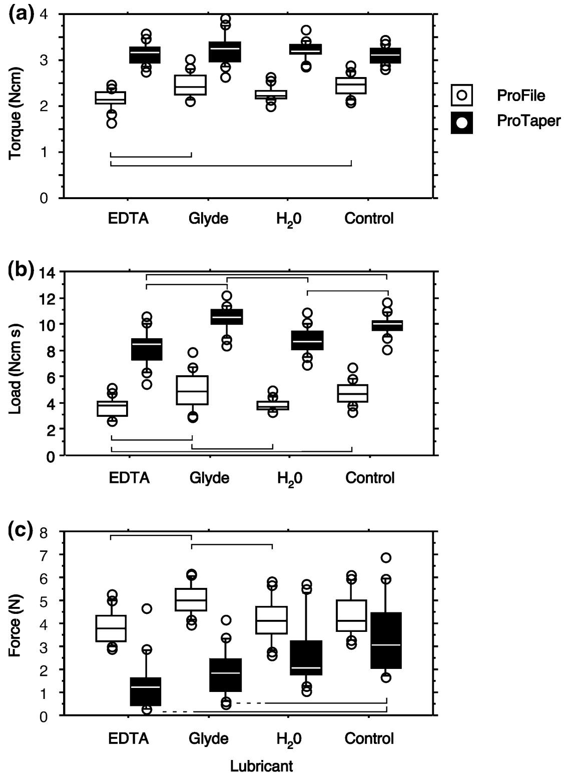

Figure 3 Box-plot diagrams of torque, torsional loads and force for experiments 1 and 2. Significant differences ($P < 0.05$) in *post-hoc* tests are indicated by horizontal bars.

amongst single dentine discs and between lubricants. Mean maximum values and standard deviations were 0.91 ± 0.11 and 1.54 ± 0.19 N for ProFile and ProTaper, respectively. Force scores for ProFile were significantly ($P < 0.005$, ANOVA) lower in the presence of water and EDTA than with Glyde, whilst Glyde and EDTA reduced force scores for ProTaper ($P < 0.005$, ANOVA, Fig. 3c).

To compare the effects of lubrication between the two instruments, all scores were recalculated and expressed as percentage of the nonlubricated control values (Fig. 4). Two-way ANOVA revealed significant differences ($P < 0.001$) between ProFile and ProTaper for both maximum torque and apically applied force (Fig. 4).

Mean reductions of torque of 11.9% (EDTA) and 6.7% (water) were found for ProFile, whilst none of the media reduced torques for ProTaper. Full torsional loads were reduced similarly for both files ($P = 0.847$, Fig. 4b), by the two liquid media whilst Glyde had no effect. Finally, the effect of lubricants was significantly different on ProFile and ProTaper ($P < 0.001$) with

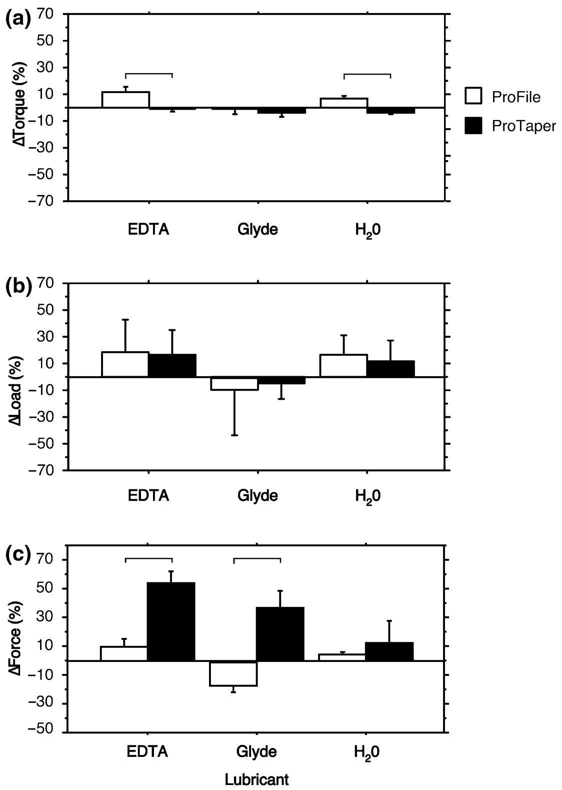

Figure 4 Bar diagrams of torque, torsional loads and force expressed as percentages relative to control data (data are expressed as mean ± SEM). Note: positive values indicate a clinically desirable effect, i.e. a reduction in torque, load and force. Significant differences in *post-hoc* tests are indicated.

regard to apically directed force (Fig. 4c). All lubricants reduced force when applied to ProTaper by mean reductions ranging from 12 to 54%, whilst Glyde led to increased force when applied to ProFile (−17.8%, Fig. 4c).

Discussion

This appears to be the first study to evaluate the effect on torque values of different media or solutions used during engine-driven rotary root canal preparation. Earlier, Yguel-Henry *et al.* (1990) had suggested that lubrication increased cutting efficacy of hand instruments, comparing NaOCl and tap water to no lubrication. They cited the ability of a lubricant to remove debris as the main factor for increased efficiency.

In the present study, irrigation solutions such as water and EDTA were generally more effective than the paste-type chelator product under investigation in decreasing torque compared with baseline scores obtained with no lubrication. This was observed both for ProFile with a radial-landed cross-section and for the more actively cutting ProTaper instrument. However, there were also differences between the actions of the lubricants when applied to the two instruments used, specifically regarding apically directed force.

It should be noted that, whilst great care was taken to standardize the approach by using milled simulated artificial root canal and by alternating the canal positions, substantial variations were present amongst scores for dentine discs. Such variability is a frequently observed phenomenon when using natural materials and may be explained by variations in dentine structure (Kinney *et al.* 2003).

In addition, this study does not completely mirror a clinical situation, as the contact time between dentine and for instance EDTA was shorter than after repeated irrigation of a (narrow and calcified) root canal. Longer exposure times may increase the chemical effect of the chelating agent, resulting in reduced torque values. Furthermore, it is not clear how wetting properties and penetration ability of paste-like chelators may be affected by the short time frame and the application modalities present in this *ex vivo* study.

In addition to the two variables 'torque' and 'force' that have been used previously to describe the action of endodontic files in rotary motion (Blum *et al.* 1999, Peters & Barbakow 2002), the integrated torque over the length of procedure was introduced to more adequately describe the full torsional load and thus amount of stress that an instrument is subjected to during the preparation of root canals. Interestingly, full torsional loads were significantly reduced for both instruments after the application of water and the aqueous EDTA solution. Much smaller changes were registered for maximum torques, but these maximum values may also reflect local dentine properties and the reaction of the instrument to those irregularities.

Apically directed forces, which were largely a function of inward feed, were reduced by all media in conjunction with ProTaper instruments, whilst Glyde led to increased forces with ProFile. This observation appears to support the hypothesis that paste-type Glyde adheres to the U-shaped grooves that are present in ProFile cross-sections and collects dentine chips, whilst fluids such as water and EDTA flush hard tissue debris away from the instrument (Yguel-Henry *et al.* 1990). Collection of debris in cutting flutes is a frequent phenomenon for rotary instruments (Eggert *et al.* 1999) and has been implicated in dulling of burs and

dentinal cracking after pin placement (Newitter *et al.* 1989). In this context, it may be assumed that any aqueous irrigant such as sodium hypochlorite or chlorhexidine solutions will be more advantageous than Glyde in conjunction with ProFile instrumentation.

Whilst lubrication depends mainly on film formation and reversible physical surface modification, it is also possible to chemically modify the surfaces that are subjected to friction. This is supposed to happen when EDTA is applied to root canal, as it removes superficial Ca^{2+} ions from dentine and brings them into solution (Hülsmann *et al.* 2003). However, EDTA solution was barely more effective than deionized water in decreasing torque under the conditions of the current experimental series. Moreover, EDTA-containing Glyde was even counterproductive when applied to ProFile instruments.

In addition, it has recently been shown that chemical interaction between ETDA and NaOCl block the tissue-dissolving capacity of the latter agent (Grawehr *et al.* 2003). Both EDTA and citric acid abolish the antimicrobial capacity of NaOCl solutions (unpublished observations). Consequently, the use of EDTA at early stages of root canal treatment is not favourable, specifically when shaping infected root canal systems (Zehnder *et al.* 2003). Instead, a high-volume flush with EDTA after finishing shaping has been recommended, that is then again flushed out with NaOCl (Yamada *et al.* 1983, Zehnder *et al.* 2003). During instrumentation, a reservoir of aqueous NaOCl in the root canal system appears favourable both from a microbiological and, based on the current results, mechanical point of view.

Whilst lubrication has been recommended for the use of NiTi rotary instrument, beneficial effects such as reduction of torque or elimination of instrument fractures have not been conclusively demonstrated. The results of the current study suggest that liquid irrigation media in fact reduce torque, but that paste-type substances are more suitable for actively cutting files.

Laboratory studies in plastic blocks have indicated that it is preferable to use soap-based lubricants when preparing simulated root canals to avoid instrument breakage (Thompson & Dummer 1997). However, the surface quality of plastic and the interaction between plastic material and the cutting instrument are different from dentine and care should be exercised when extending observations from these laboratory studies to clinical applications. More research is needed to identify suitable lubricants that do not interfere with disinfecting agents and that are adequate for different instrument cross-sections.

Conclusions

Lubrication of root canals using aqueous solutions decreased torque and force, but this effect was mostly independent of the use of EDTA. Furthermore, the paste-type lubricant under investigation was less beneficial than aqueous counterparts, as it showed untoward effects when used in conjunction with a rotary instrument with a U-shaped cross-section.

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